

Decoherence and Dephasing in Multilevel Systems

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Decoherence and dephasing properties of ideal two-level qubit systems are well known in the literature since the introduction of the Caldeira-Leggett model in the early 1980s. Majority of work on decoherence today still focuses on idealized simple systems for the sake of obtaining rigorous analytic solutions. We examine in this work the decoherence and dephasing properties of realistic multilevel systems interacting with a bosonic environmental bath in detail numerically using the density matrix master equation formalism for an N -level quantum system in the range $N=[2-20]$. The physical model we start with is that of an rf-SQUID in the Macroscopic Quantum Coherence (MQC) regime although the variety of the parameters used in the model (energy degeneracy, symmetry of the potential, system-noise coupling, environmental temperature and the noise spectrum) cover a wide range of applicability to render sufficient generality of our results. The results indicate that, despite the standardly expected exponential or Gaussian decoherence, there is a much larger variety of the short-time behaviour, depending on the quantum state of the system. We find that the role played by the energy degeneracy of the chosen qubit crucially affects the decoherence and dephasing properties which is surprisingly more influential for multilevel systems than the two level ones. Another surprise in our results is that the decoherence time is not a monotonous function with the number of levels for a large variety of parameter ranges.

We are currently employing coherent state path integral methods to find the influence functional for the multilevel systems. We thus expect a majority of our numerical results to be verified analytically. Although vastly simple to handle, we are not aware of any existing model on multilevel decoherence and dissipation at the scrutiny we deal with in this work.